

**Instituto Tecnológico y de Estudios Superiores de Occidente**

**Repositorio Institucional del ITESO**

**[rei.iteso.mx](http://rei.iteso.mx)**

---

Departamento de Electrónica, Sistemas e Informática

DESI - Artículos y ponencias con arbitraje

---

2010-07

# Multispectral Classification of Remote Sensing Imagery for Archaeological Land Use Analysis: Prospective Study

Villalón-Turrubiates, Iván E.; Llovera-Torres, María J.

---

Iván E. Villalón-Turrubiates y María J. Llovera-Torres, "Multispectral Classification of Remote Sensing Imagery for Archaeological Land Use Analysis: Prospective Study", in Proceedings of the 2010 IEEE International Geoscience and Remote Sensing Symposium (IGARSS): Global Vision for Local Action, Honolulu, Hawaii, 2010, pp. 323-326.

Enlace directo al documento: <http://hdl.handle.net/11117/3295>

*Este documento obtenido del Repositorio Institucional del Instituto Tecnológico y de Estudios Superiores de Occidente se pone a disposición general bajo los términos y condiciones de la siguiente licencia:*  
<http://quijote.biblio.iteso.mx/licencias/CC-BY-NC-2.5-MX.pdf>

*(El documento empieza en la siguiente página)*

# MULTISPECTRAL CLASSIFICATION OF REMOTE SENSING IMAGERY FOR ARCHAEOLOGICAL LAND USE ANALYSIS: PROSPECTIVE STUDY

Ivan E. Villalon-Turrubiates<sup>1</sup>, *Member, IEEE*, and Maria J. Llovera-Torres<sup>2</sup>

<sup>1</sup>Universidad de Guadalajara, Centro Universitario de los Valles, México, villalon@ieee.org

<sup>2</sup>Universidad Autónoma de San Luis Potosí, México, llovera\_torres@alumnos.uaslp.edu.mx

## ABSTRACT

Much of human history can be traced through the impacts of human actions upon the environment. The use of remote sensing technology offers the archeologist the opportunity to detect these impacts which are often invisible to the naked eye. The extraction of remote sensing signatures from a particular geographical region allows the generation of geophysical signature maps; this can be achieved using an accurate and recently developed multispectral image classification approach based on pixel statistics for the class description, which is referred to as the Weighted Pixel Statistics method. This paper presents the prospective study of the effectiveness that this approach provides for supervised segmentation and classification of sensed archaeological signatures for land use analysis. The results obtained with this study uses real multispectral scenes obtained with remote sensing techniques (high-resolution synthetic aperture radar) to probe the efficiency of the classification technique.

## 1. INTRODUCTION

Generations of archaeologists have longed for some way of learning from archaeological sites without actually having to dig them. The prominent archaeologist Lewis Roberts Binford, Ph.D., once said "*ideally, we should have an X-ray machine which would allow us to locate and formally evaluate the range of variation manifest in cultural features*" [1]. Recently, Binford's elusive X-ray machine has been actualized in a series of increasingly and highly sophisticated remote sensing contrivances. These new techniques can (prior to excavation) provide information of where the archeological sites are and what they contain.

Surface studies are necessary to obtain data that excavations cannot provide. Some examples are the applications of aerial and satellite photography, which shows a wide panorama of the archaeological site, allows examining ground marks, find walls from former occupations, etc. [2]. In some cases is possible to identify in the ground the necessary elements to study the materials and establish a chronology (even a tentative one), shows the environmental relationship with the site, important aspects as space dimension and distances to another related sites [3].

The extension and complexity of the site are necessary elements for planning and managing the archaeological research site.

The geophysical techniques employed in prospecting studies are important because provides information to the researcher to help solving difficulties, to act within large terrain extensions, to detect archaeological contexts and maximize the excavation efficiency [4].

Considerable progress has been made generally in the application of remote sensing (RS) techniques to both research and operational problems for urban assessment, urban planning and natural resources management. Modern applied theory of signal and image processing for land cover and land use analysis is now a mature and well developed research field, presented and detailed in many works ([5] thru [8] and the references therein are only some indicative examples).

Although the existing theory offers a manifold of statistical techniques to tackle with the particular geophysical monitoring problems, in many applications areas there still remain some unresolved crucial theoretical and data processing problems.

One of the most important problems to be solved is particularly related to the extraction of physical characteristics for applications in archaeological land use analysis.

Modern digital signal and image processing techniques are currently used by archaeologist to detect the impacts of human actions upon the environment. This information can be used to address issues in human settlement, environmental interaction, and climate change [9].

Archeologists want to know how ancient people successfully adapted to their environment and what factors may have led to their collapse or disappearance.

Remote sensing can be used as a methodological procedure for detecting, inventorying, and prioritizing surface and shallow-depth archeological information in a rapid, accurate, and quantified manner [10].

The application of an accurate tool recently developed in [11] for supervised segmentation, classification and quantification of the sensed archaeological signatures (SAS) using multispectral remote sensing (MRS) imagery for land use analysis is based on the analysis of pixel statistics, and is referred to as the weighted pixel statistics (WPS) method.

## 2. MULTISPECTRAL IMAGING

Multispectral imaging is a technology originally developed for space-based imaging, are the main type of images acquired by RS radiometers. Usually, MRS systems have from 3 to 7 radiometers; each one acquires one digital image (called scene) in a small band of visible spectra, ranging 450 nm to 690 nm, called red-green-blue (RGB) regions [12].

For different purposes, combinations of spectral bands can be used. They are usually represented with red (R), green (G) and blue (B) channels. This is referred to as True-Color RS imagery [12].

The wavelengths for the spectral bands are 450-520 nm for Blue, 520-600 nm for Green, and 600-690 nm for Red (the values are approximated, exact values depends on the particular MRS instruments [13]).

## 3. WEIGHTED PIXEL STATISTICS METHOD

The weighted pixel statistics (WPS) classification rule is computationally simple. An extensive study was performed in [11] to probe that the accuracy obtained with this classification process is more efficient (both qualitatively and quantitatively) compared with other more computationally intensive algorithm (as the weighted order statistics method [8]).

The WPS algorithm is characterized by the mean and variance values of the sensed archaeological signatures (SAS) to be classified (defined as classes) and the Euclidean distances based on the Pythagorean Theorem.

The training data for class segmentation requires the number of SAS to be classified ( $c$ ); the means matrix  $\mathbf{M}$  ( $c \times c$  size) that contains the mean values  $\mu_{cc}$ : ( $0 \leq \mu_{cc} \leq 255$ , gray-level) of the SAS classes for each RGB bands; and the variances matrix  $\mathbf{V}$  ( $c \times c$  size) that contains the variances of the SAS classes for each RGB bands. The matrix  $\mathbf{M}$  and  $\mathbf{V}$  represents the weights of the classification process.

Next, the image is separated in the spectral bands (R, G and B) and each ( $i, j$ )-th pixel is statistically analyzed calculating the means and variances from a neighborhood set of  $5 \times 5$  pixels for each RGB band, respectively.

To compute the output of the classifier, the distances between the pixel statistics and the training data is calculated using Euclidean distances based on the Pythagorean Theorem for means and variances, respectively.

The decision rule used by the WPS method is based on the minimum distances gained between the weighted training data and the pixel statistics.

The WPS techniques provide a high level of SAS segmentation and classification.

Figure 1 shows the detailed processing structure of the WPS classifier.

## 4. SAS SIMULATION EXPERIMENT

In the reported here simulation results, a SAS electronic map is extracted from the MRS high-resolution image using the WPS method. Three level SAS are selected for this particular simulation process, moreover, unclassified zones must be also considered (2-bit classification) as





-  – SAS relative to natural land cover zones of the MRS.
-  – SAS relative to archaeological land zones of the MRS.
-  – SAS relative to modern land use zones of the MRS.
-  – Unclassified zones of the SAS map.

Figure 2 shows the first scene: high-resolution ( $1024 \times 1024$ -pixels) MRS image in TIFF format [14] corresponding to the Giza Necropolis, on the outskirts of Cairo, Egypt. Figure 3 shows the SAS map extracted from Figure 2 and obtained applying the WPS method for the adopted ordered weight vector.

Figure 4 shows the second scene: high-resolution ( $1024 \times 1024$ -pixels) MRS image in TIFF format [14] corresponding to the Temple of Kukulcan from the pre-Hispanic city of Chichen-Itza located in the state of Yucatan, Mexico. Figure 5 shows the SAS map extracted from Figure 4 and obtained applying the WPS method for the adopted ordered weight vector.

The WPS method employs the three RGB bands from the original image; therefore, using the statistical pixel-based information the SAS map obtained shows a high-accurate classification without unclassified zones.

## 5. CONCLUDING REMARKS

From the simulation results one may deduce that the applied WPS classifier provides a high-accurate classification without unclassified zones because it uses more robust information in the processing (several image spectral bands). The reported here simulation results shows the qualitative analysis of the overall performance of the WPS method for land use analysis as an auxiliary tool in archaeological information retrieval.

This paper presents the prospective study of the effectiveness that this approach provides for supervised segmentation and classification of sensed archaeological signatures for land use analysis. The quantitative analysis and data interpretation are a matter of further studies.

## 6. ACKNOWLEDGMENT

The authors would like to thank the “Programa de Mejoramiento del Profesorado PROMEP” of the Public Education Secretary (SEP) of Mexico, to the University of Guadalajara for the resources provided for this research, and to the Department of Humanities and Social Sciences of the Autonomous University of San Luis Potosi.

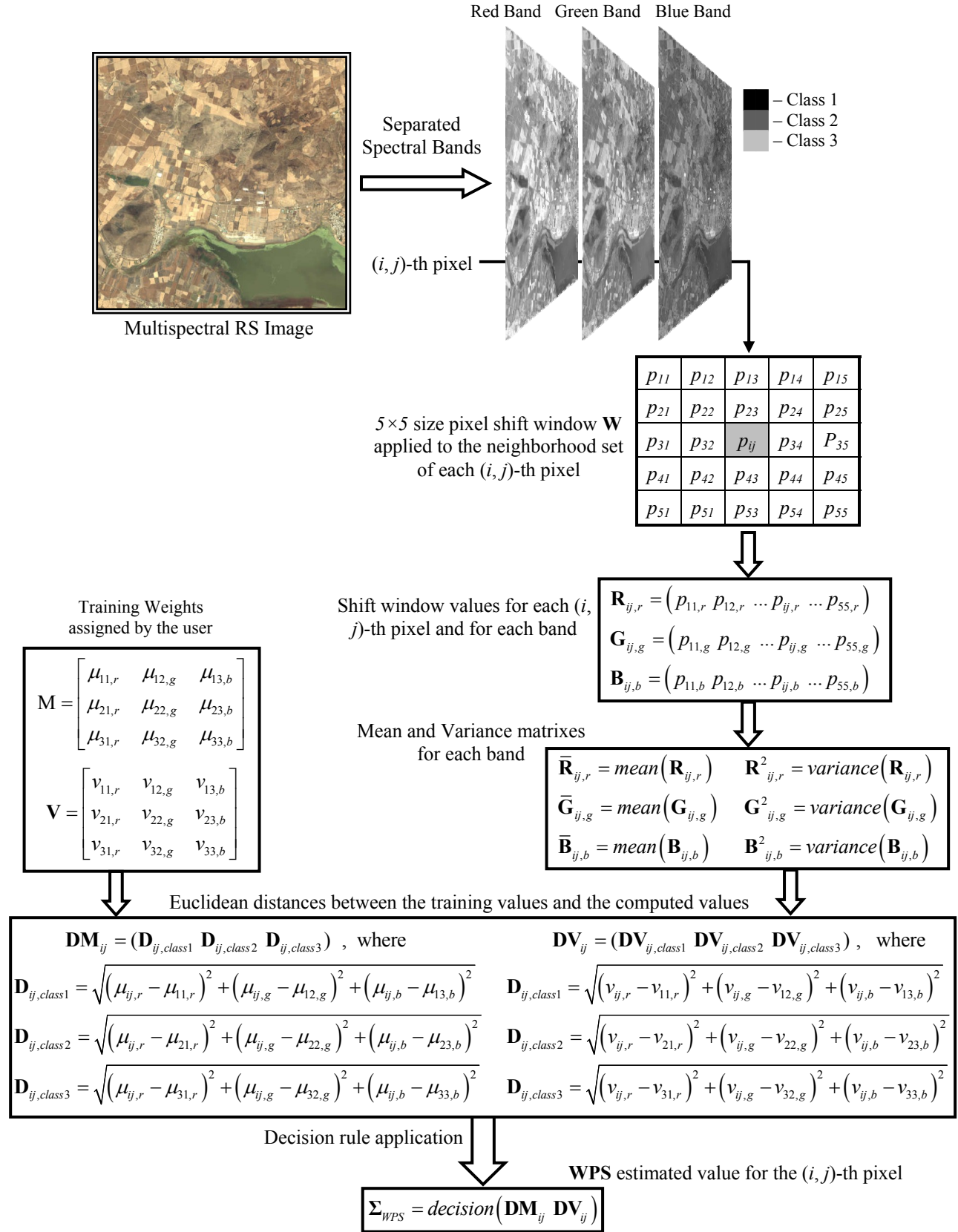


Figure 1. Computational algorithm of the WPS method.



Figure 2. Original MRS image for the first scene.



Figure 4. Original MRS image for the second scene.

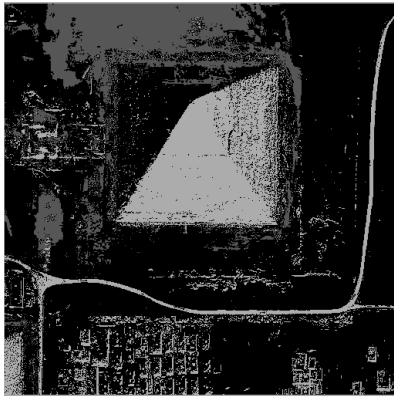


Figure 3. SAS map extracted from the first scene.

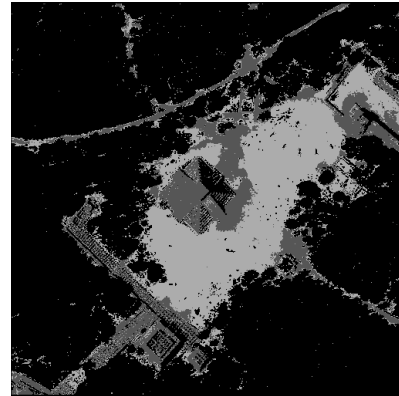


Figure 5. SAS map extracted from the second scene.

## 7. REFERENCES

- [1] L.R. Binford, "A Consideration of Archaeological Research Design", in *American Antiquity*, pp. 425-441, 1964.
- [2] C. Gamble, *Arqueología Básica*, Ariel, Spain, 2001.
- [3] J. Litvak-King, *Introducción a la arqueología, todas las piedras tienen 2000 años*, Trillas, Mexico, 1986.
- [4] L. Barba-Pingarrón, *The ordered application of geophysical, chemical and sedimentological techniques study of archaeological sites: the case of san José Ixtapa*, Thesis of the University of Georgia, U.S.A., 1984.
- [5] S.W. Perry, H.S. Wong, and L. Guan, *Adaptive Image Processing: A Computational Intelligence Perspective*, CRC Press, U.S.A., 2002.
- [6] Y. Shkvarko, and I. Villalon-Turrubiates, "Remote sensing imagery and signature fields reconstruction via aggregation of robust regularization with neural computing", in *Advanced Concepts for Intelligent Vision Systems*, J. Blanc-Talon, W. Philips, D. Popescu and P. Scheunders, Springer-Verlag, Germany, pp. 865-876, 2007.
- [7] R. Porter, D. Eads, D. Hush, and J. Theiler, "Weighted order statistics classifiers with large rank-order margin", in *Proceedings of the 20<sup>th</sup> International Conference on Machine Learning*, Washington U.S.A., 2003.
- [8] P.M. Mather, *Computer Processing of Remotely-Sensed Images*, John Wiley & Sons, U.S.A., 2004.
- [9] R. Williamson, "Remote Sensing Methods", *Advances in Science and Technology for Historic Preservation*, Plenum Press, U.S.A., 2008.
- [10] F. Miller, and D. Lee, "Applications of Ecological Concepts and Remote Sensing Technologies in Archeological Site Reconnaissance", *Applications of Space-Age Technology in Anthropology*, C. Behrens, and T. Sever, NASA Press, U.S.A., 1991.
- [11] I.E. Villalon-Turrubiates, "Weighted Pixel Statistics for Multispectral Image Classification of Remote Sensing Signatures: Performance Study", *Proceedings of the 5<sup>th</sup> IEEE International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE)*, Mexico City, pp. 534-539, 2008.
- [12] H. Hough, *Satellite Surveillance*. U.S.A.: Loompanics Unlimited, U.S.A., 1992.
- [13] J. R. Jensen, *Introductory Digital Image Processing: A Remote Sensing Perspective*, Prentice-Hall, U.S.A., 2005.
- [14] GeoEye – *Innovative Geospatial Products and Solutions*, <http://www.geoeye.com>, 2009.